THE REVOLUTION HAS NOT BEEN TELEVISED

A Case Study in Cost-effective, Environmentally-Advantageous Kilowatt-scale CHP at USMint

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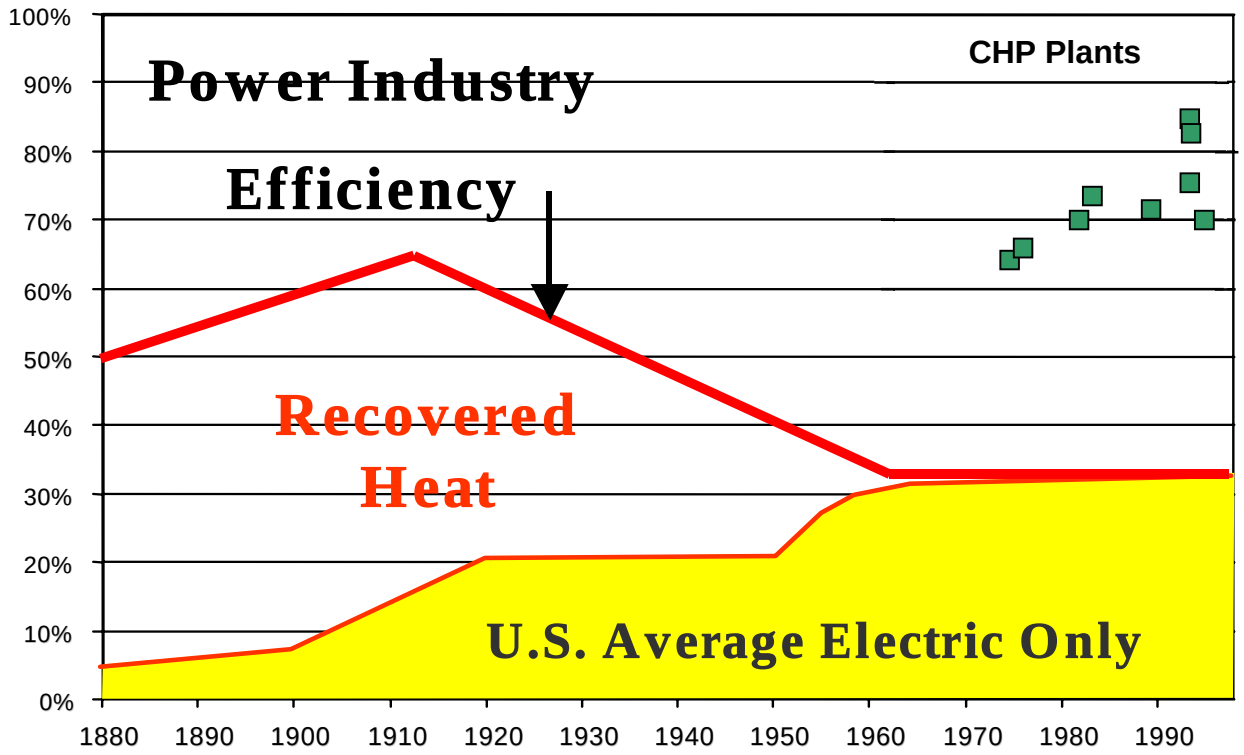
Creating Value from Steam Pressure

THE REALITY: Shouldn't we be able to go "back to the future"?

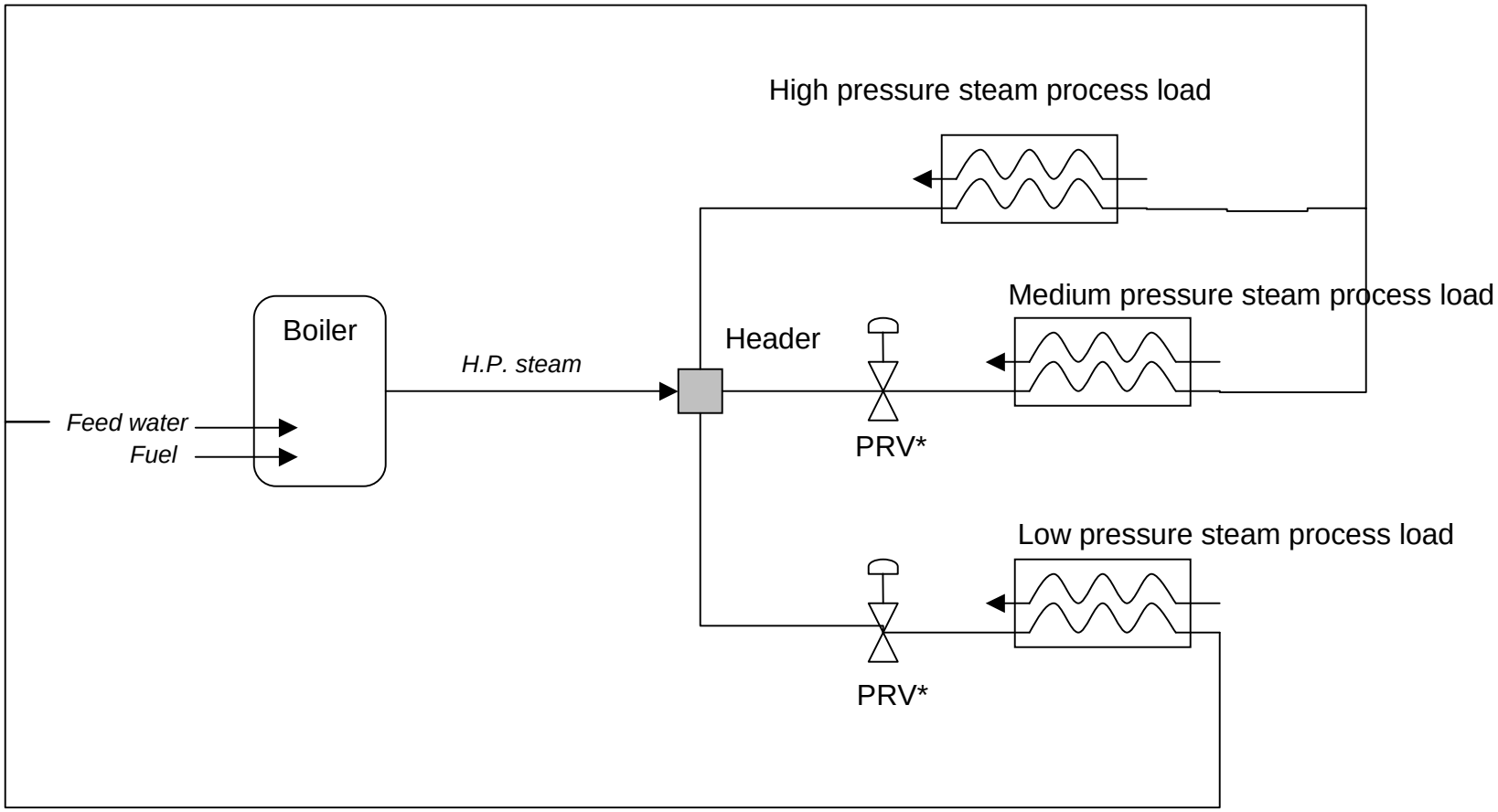


TURBO STEAM

THE REALITY:

	116 year-old Technology	Central Power Plant, ca. 2001
Installed Capital Cost	$300 – 1,000/kW	$500 – 2,000+/kW
Power Generation Efficiency	>80%	33% (U.S. average)
Marginal Cost of Electricity, at the point of use	1 – 3 cents/kWh	4 – 10 cents/kWh
Minimum Economic Size	50 kW	~50,000 kW
Economic Potential for Waste Heat Recovery (CHP)?	Implicit in Design	No
Economic Potential for CCHP?	Yes	No
CO_2 Emissions, at the point of electricity use	0 – 1,000 lbs/MWh	1,000 – 2,300 lbs/MWh

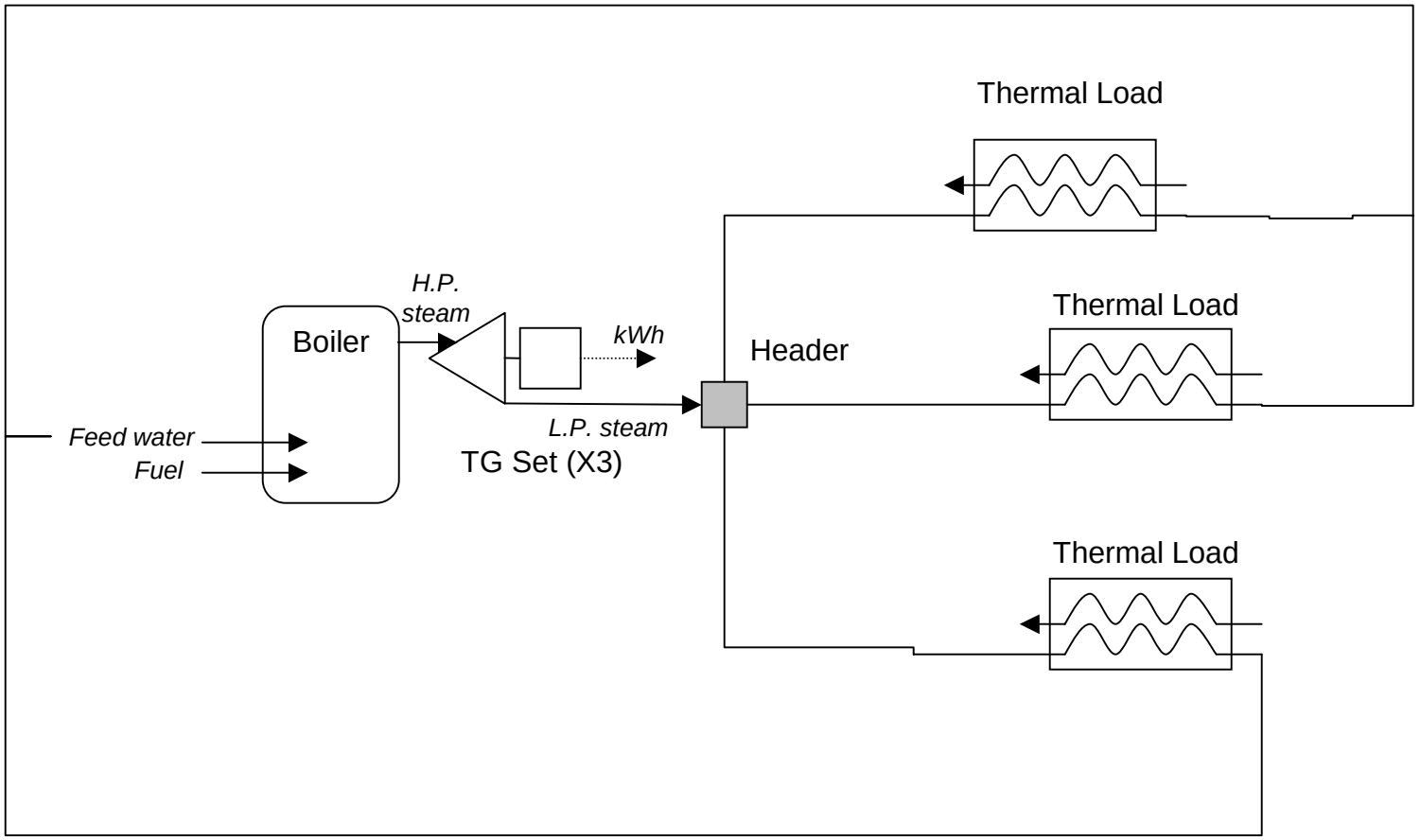
Typical steam system design



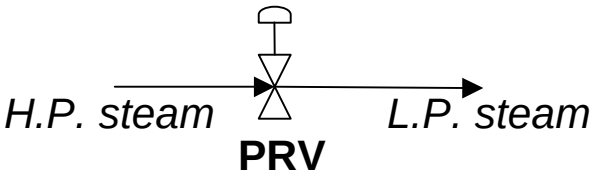
**PRV = Pressure Reducing Valve*

A backpressure turbine delivers the same pressure drop as a PRV -- but produces useful electricity in the process.

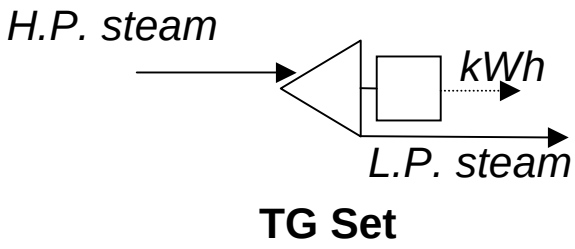
Morning Star Design



This design generates power at the efficiency of Morning Star's boiler – or higher!



Thermodynamics	
1st Law Balance	**PRV Efficiency**
H.P. energy = L.P. energy	~100%



H.P. energy = L.P. energy + kWh	~Boiler efficiency = 80 – 85% PRV efficiency ~ power generation efficiency!

This is almost 3X the efficiency of the grid!

Economic considerations

	USMint / Turbosteam Backpressure Turbine-Generator
Description	231 kW generator reduces 150 psig steam down to 5 psig Process pressure
Installed Capital Cost	$ ($108,900) Equipment + $90,000 Installation Cost = $ (90,000) Total Cost (**$861/kW**) (The Turbine was installed at no cost to the Mint)
Marginal Cost of Power Generation	12 dollars/MMBTu steam $1000/year average O&M cost **All-in cost = 4.5 cents/kWh**

On-site CHP is more cost-effective than the state-of-the-art central power plant!

Case Study: USMint

- USMint has installed a 231 kWe cogen plant to produce:
  - 2% of its electric load
  - Approximately 95% of the Steam used is for heating. The reminder 5% is used for the plant heat processing load.
- The building is located in Philadelphia, PA
- This plant provide heating for 517,218 Sq feet
- Heating load is seasonal with (11,500 lbs/hour at peak)
- Operating season is 6 months
- Process steam load delivered by Trigen District heating plant, @ 150 psig

  Equivalent to $12/Mlb steam
  - Delivery pressure = 150 psig
- The plant uses 26,140 MWh/year, at an average price of 7 cents/kWh (Based on Fiscal Year 2001 consumption)

Case Study: USMint

- In Nov. 1997: Started up one 231 kW Turbosteam backpressure steam turbine generators.
  - To feed heating load and some process load

	November 1999 - December 2000							
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Total**
Electricity Produced (kWh)	53,516	96,992	70,174	117,818	114,950	89,898	6,328	549,676
Electric Savings	$4,562.52	$6,568.63	$6,270.14	$7,818.14	$7,191.88	$6,156.07	$156.43	$38,723.81
Incremental Steam Cost	$1,581.60	$2,538.57	$1,983.01	$3,310.97	$3,312.73	$2,617.53	$218.65	$15,563.06
Net Savings	$2,980.92	$4,030.06	$4,287.13	$4,507.17	$3,879.15	$3,538.54	-$62.22	$23,160.75

Mint’s BackPressure Turbine

TURBO STEAM

Continuation

TURBO STEAM

Sample Back Pressure Turbine Data

		Metered Data									
		Into the BPT		Out of the BPT		Enthalpy		Energy (Mbtu) to	Incremental	Cost at	Cost
Date/Time	Month	Steam Flow	Pressure	Pressure	kWh	Steam In	Steam Out	BPT for electricity	Steam (Mlbs)	$15/Mlb	per kWh
12/23/1999 0:00	12	12,524	130.3	4.3	208	1,193.5	1,155.3	478.5	0.401	$6.01	$0.0289
12/23/1999 1:00	12	12,273	129.6	4.3	207	1,193.5	1,155.3	468.0	0.392	$5.88	$0.0284
12/23/1999 2:00	12	11,823	125.3	4.3	199	1,193.0	1,155.3	444.9	0.373	$5.59	$0.0281
12/23/1999 3:00	12	11,973	125.9	4.3	200	1,193.0	1,155.3	451.3	0.378	$5.67	$0.0284
12/23/1999 4:00	12	12,067	125.9	4.3	199	1,193.0	1,155.3	454.9	0.381	$5.72	$0.0287
12/23/1999 5:00	12	12,133	126.9	4.3	202	1,193.1	1,155.3	458.8	0.385	$5.77	$0.0286
12/23/1999 6:00	12	12,120	126.5	4.3	200	1,193.1	1,155.3	457.7	0.384	$5.75	$0.0288
12/23/1999 7:00	12	11,605	121.0	4.3	192	1,192.4	1,155.3	430.7	0.361	$5.42	$0.0282
12/23/1999 8:00	12	11,606	120.3	4.3	191	1,192.4	1,155.3	429.9	0.361	$5.41	$0.0283
12/23/1999 9:00	12	11,328	117.4	4.3	185	1,192.0	1,155.3	415.4	0.348	$5.23	$0.0283
12/23/1999 10:00	12	11,146	113.7	4.3	179	1,191.5	1,155.3	403.4	0.339	$5.08	$0.0284
12/23/1999 11:00	12	10,715	110.0	4.3	173	1,191.0	1,155.3	382.4	0.321	$4.82	$0.0278
12/23/1999 12:00	12	10,565	107.8	4.3	169	1,190.7	1,155.3	374.0	0.314	$4.71	$0.0279
12/23/1999 13:00	12	10,142	103.3	4.3	161	1,190.1	1,155.3	352.5	0.296	$4.44	$0.0276
12/23/1999 14:00	12	9,872	99.7	4.3	154	1,189.6	1,155.3	337.8	0.284	$4.26	$0.0277
12/23/1999 15:00	12	9,838	98.0	4.3	151	1,189.3	1,155.3	334.0	0.281	$4.21	$0.0279
12/23/1999 16:00	12	9,247	91.5	4.3	138	1,188.2	1,155.3	304.2	0.256	$3.84	$0.0278
12/23/1999 17:00	12	8,884	88.4	4.3	133	1,187.7	1,155.3	287.6	0.242	$3.63	$0.0273
12/23/1999 18:00	12	8,859	87.6	4.3	131	1,187.6	1,155.3	285.7	0.241	$3.61	$0.0275
12/23/1999 19:00	12	9,045	90.5	4.3	136	1,188.1	1,155.3	296.1	0.249	$3.74	$0.0275
12/23/1999 20:00	12	9,577	95.2	4.3	146	1,188.8	1,155.3	321.0	0.270	$4.05	$0.0277
12/23/1999 21:00	12	9,999	101.0	4.3	155	1,189.7	1,155.3	344.0	0.289	$4.34	$0.0280
12/23/1999 22:00	12	10,369	104.3	4.3	162	1,190.2	1,155.3	361.8	0.304	$4.56	$0.0281
12/23/1999 23:00	12	10,544	106.1	4.3	166	1,190.5	1,155.3	370.6	0.311	$4.67	$0.0281

Net Results

- The turbine-generator installed delivered better overall economics than the current state of the art in central power plants – at just 1/500th of the size.
  - Simple payback = < 2 years
  - Estimated $24,100 savings per system per year
- This financially motivated installation is currently reducing CO_2 emissions by 2,000 tons/year
  - Similar reductions have occurred for criteria pollutants (NOx, SOx, etc.)

Bottom line: The revolution has arrived

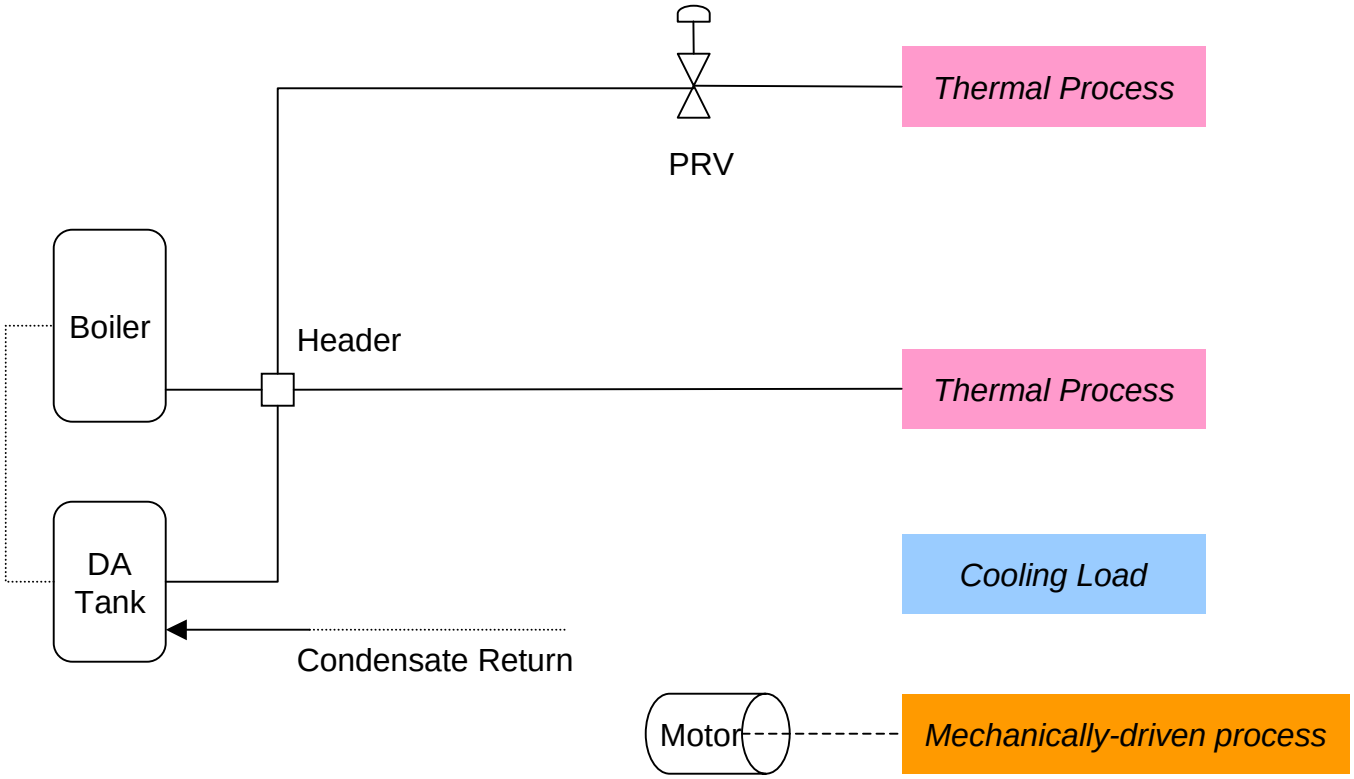
Onsite, environmentally-beneficial CHP in sub-MW sizes is available, proven and cost effective.

Can we help you find opportunities?

	Probably not attractive	Probably attractive	Drop-dead gorgeous
Steam flow rate	<3,000 lbs/hr	>3,000 lbs/hr	>10,000 lbs/hr
Inlet pressure	<125 psig	>125 psig	>150 psig
Pressure drop	<100 psi	>100 psi	>150 psi
Price of electricity	<1.5 ¢/kWh	>2 ¢/kWh	>6 ¢/kWh
Capacity factor	<25%	>25%	>50%

In short, on almost any food processing plant, district heating plant, Chemical and Lumber plant, there is an opportunity.

Where will you find opportunities?



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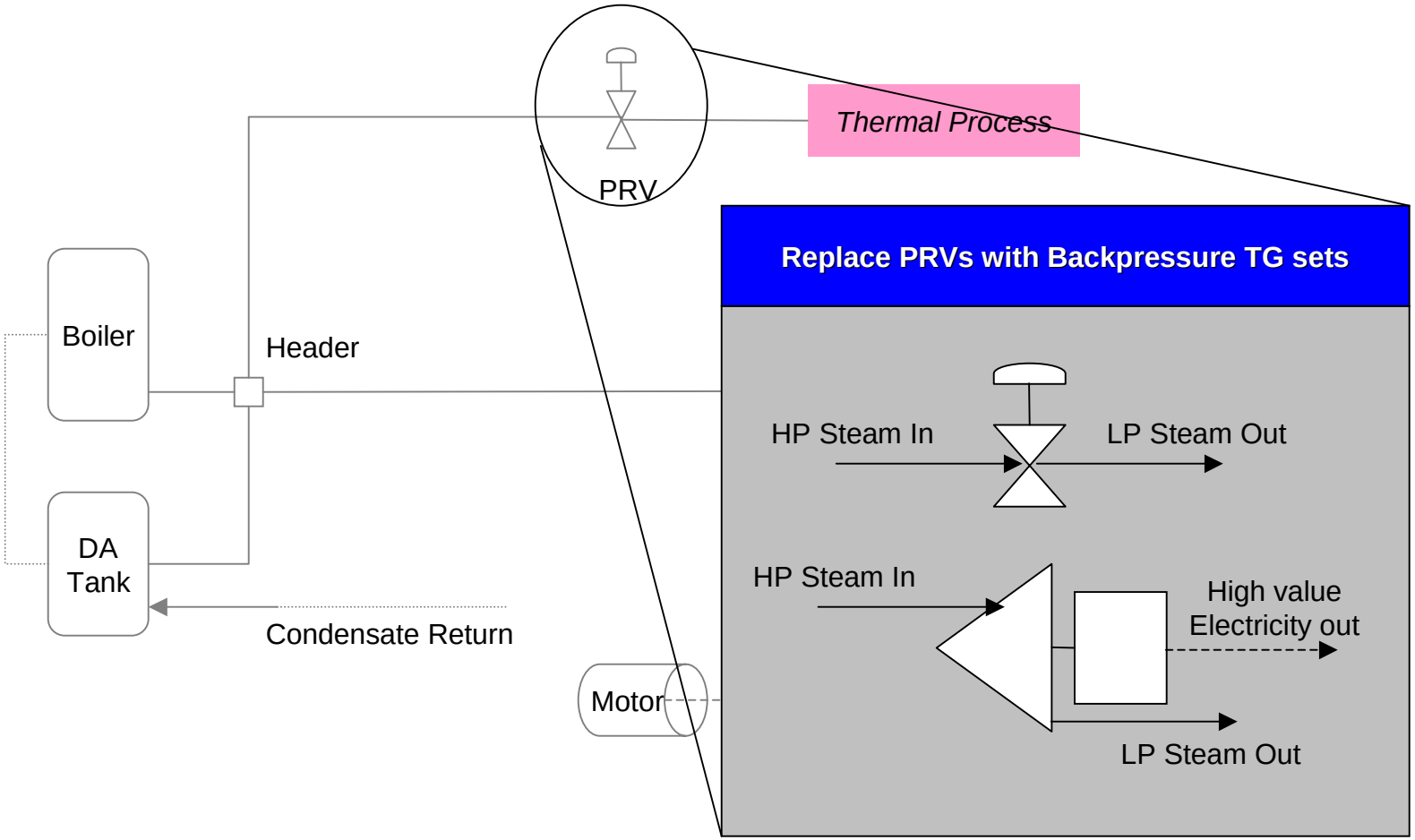

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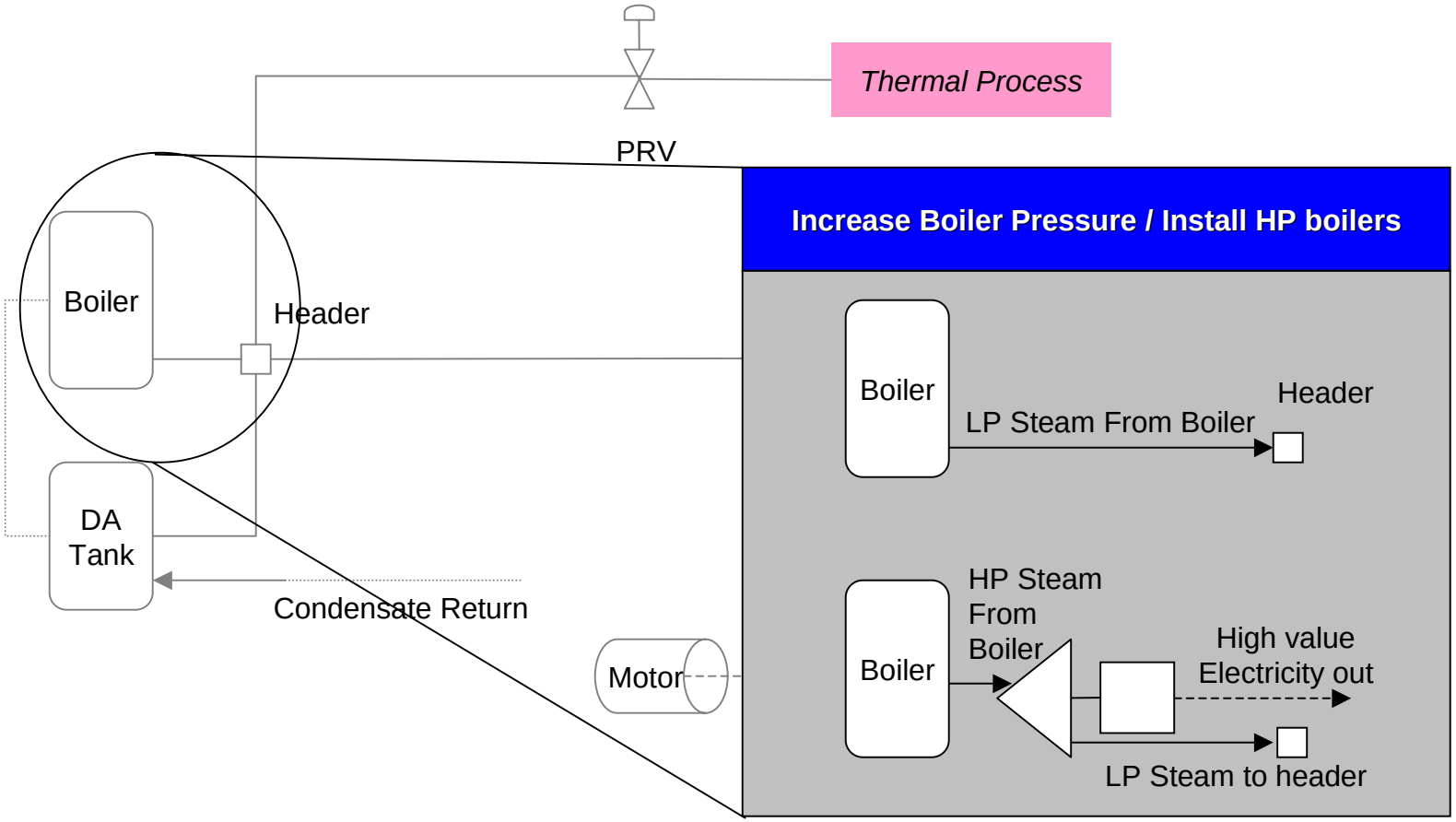

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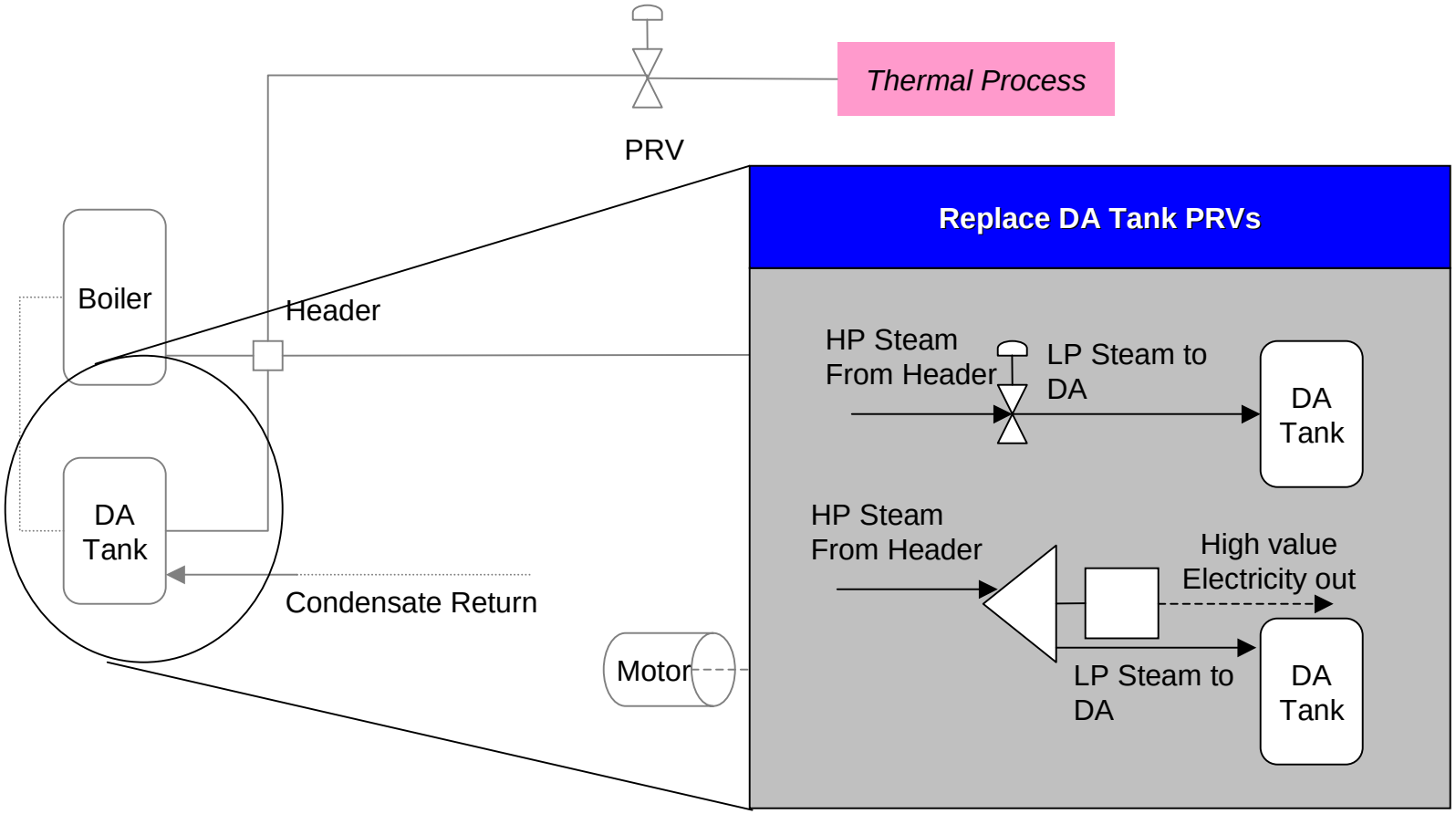

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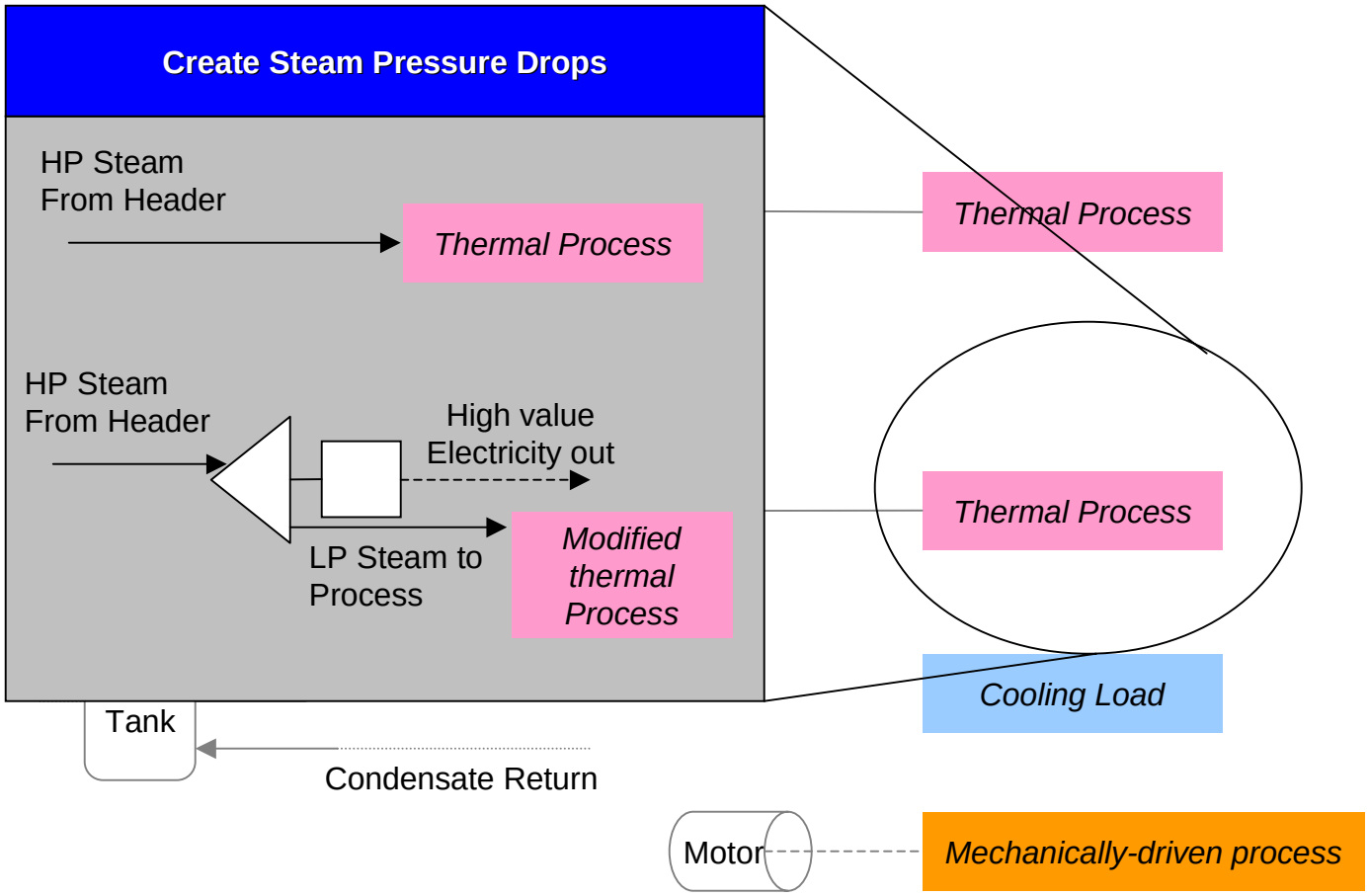

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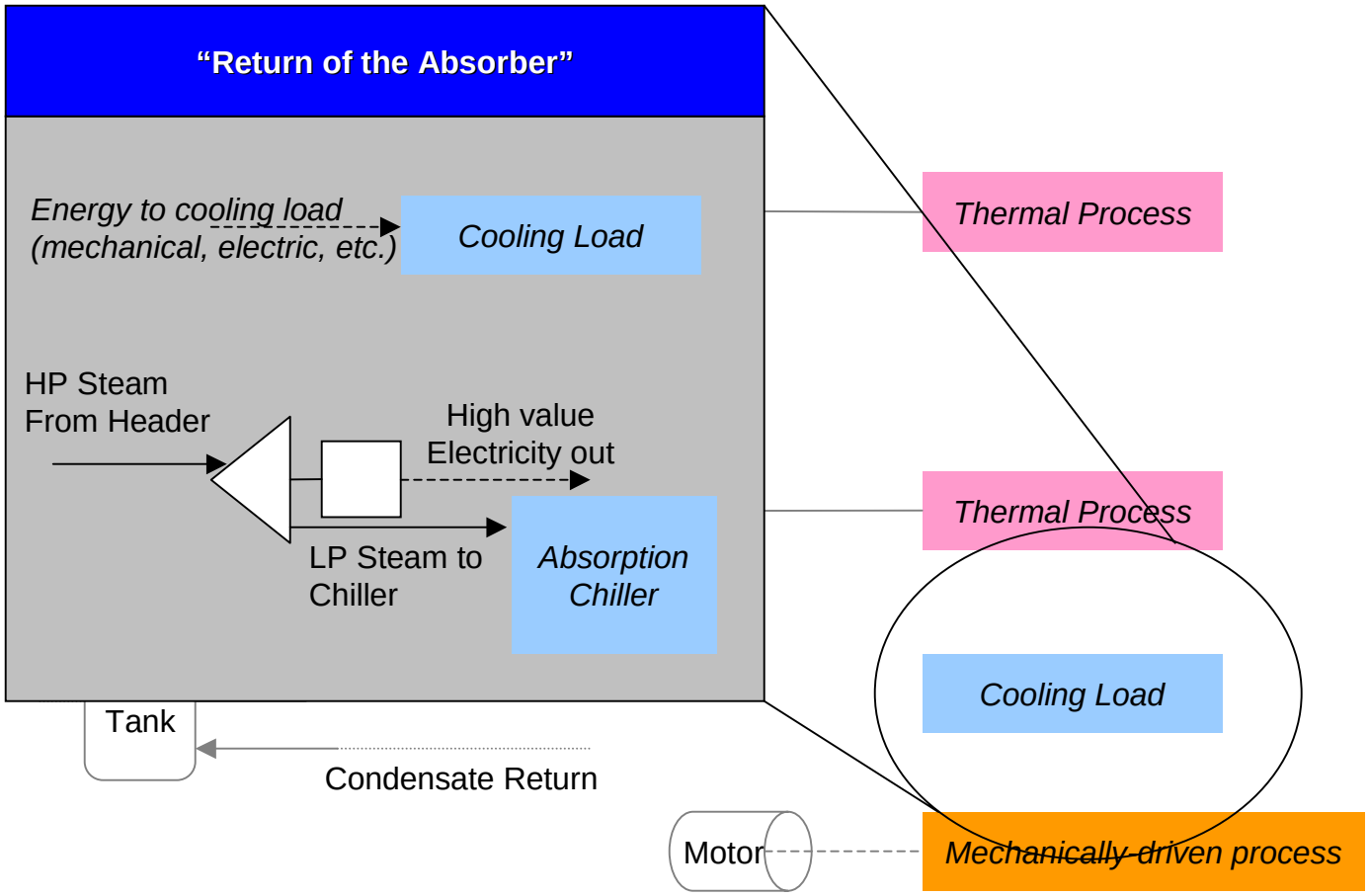

We know that this technology is not glamorous but:

- **It works**
- **It is proven**
- **It is reliable**
- **And it is the most efficient way to generate electricity**

You don’t have to believe me !

As a steam plant owner/operator, you do not need to wait for DG / CHP – you just have to know where to look. Remember that deferring this purchase is increasing your long term cost and your plant inefficiency